

Iron Ropes for the Cornish Mines? Technology Transfer between Saxony and Falmouth c.1840

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Abstract

This paper traces the technical origins of the introduction of wire ropes into the mines of the Harz Mountains in Germany and the subsequent transfer of technical information to the Royal Cornwall Polytechnic Society, Falmouth. The paper emphasises the link between the invention and development of the 'man engine' in both Germany and Cornwall, and the associated use of wire rope in this technology. Finally, consideration is given to the related internal structure and the strength of these first wire ropes.

The introduction of wire ropes - viz. ropes made of iron wire rather than of woven vegetable fibres - into the Cornish mines, and into other mines throughout the United Kingdom, is inseparably linked with the invention, development and construction of the 'man-engine' into the Cornish mines, with, at the same time, the founding of a proper wire rope manufacturing capability in Great Britain.

The origins of the manufacture of wire are lost in antiquity, but the processing of metallic filaments or shreds, known as 'wire', has been traced by good authorities as far back as the early Egyptians. However, the present method of wire manufacture, (i.e. that of 'drawing' a metal rod through a small hole in a 'die' in order to reduce its diameter) appears to have originated in Germany at some time during the 14th century.

In England in the mid-17th century the first mechanical wire mill proper was established at Sheen, near Richmond, and from this date the industry steadily developed to become, by the 19th century, a significant part of our national manufacturing base. The foundations of the industry, however, were really established in the 18th century as the number of specialist wire manufacturers slowly increased. A few examples of firms that started business at this time give an excellent feel for how the industry developed. For example, in 1708 a John Webster, who was in business as a wholesale ironmonger, perceiving the future potential for 'wire', and following an 'astute marriage' to an heiress, founded the firm of Webster, Horsfall and Lean of Birmingham in 1720 - a firm that to this day still specialises in wire manufacture. The firm of Royston & Sons was started in Halifax in 1797 specifically to manufacture 'carding' wire, a product required by the flourishing woollen and associated industries to disentangle fibres prior to spinning and to raise the nap on finished cloth. At the beginning of the 19th century, Nathaniel Greening (a practical wire drawer) and John Rylands set up a wire-making factory in the Warrington area, a district that was subsequently quick to develop as the centre of the English wire making industry. Again, almost two hundred years after its founding, the firm of Rylands-Whitecross still flourishes as specialist wire producers and wire product manufacturers.

However, the manufacture of rope from wire had to wait until 1840 when Messrs. Gordon Liddel¹ and Newall founded the firm of R.S. Newall solely to manufacture this new 'wire' product, a technological development that stemmed directly from Lewis Gordon's 1838 visit to the mines of the Harz mountains in Germany. Gordon described technical details that he had seen in Germany in a subsequent communication with the Royal Cornwall Polytechnic Society (RCPS) in Falmouth, who later published his communication 'Abstract

from notes on the power ladders used in the Harz Mines' in their 9th (1841) Annual Report. However, even before being appraised of a potentially radical new technology by Gordon, mining engineers in Cornwall, specifically under the auspices of the Royal Cornwall Polytechnic Society, had independently already begun to investigate for themselves the developments and improvements that were being reported from the mines of Clausthal in the Harz mountains.

The Cornwall Polytechnic Society was founded in 1833 and in its first proceedings is contained a report of a letter having been read from Charles Fox² offering 'premiums' (i.e. prizes) of 18 guineas for the best improvements on the present method of ascending and descending in mines. At this date the only method of obtaining access to the working face of a mine was by negotiating a series of ladders. The following extract from the 1834 Proceedings of the Cornwall Polytechnic Society, graphically identifies the physical hardship endured by miners just to reach their place of work in the mine itself:

The exertion of ascending and descending these ladders, which in the deep mines necessarily extend to depths of from 1200 to 1500 feet, is laborious and painful in the extreme and often renders them totally inaccessible to the scientific and curious enquirer. The daily requirement of this fatiguing exercise is attended with the most pernicious consequences to the miner, tending particularly to impair his physical energies, to injure his health and considerably to shorten the duration of his life.

Various plans and models were submitted to the Society which aimed at achieving a mechanical means for raising and lowering miners to and from their actual place of work. In the RCPS report of 1834 a number of plans for man raising machinery were submitted to the Committee and further premiums were offered for improvements to these plans which would hopefully lead to the successful installation a mechanical 'man-engine' into the Cornish mines. These first plans were examined by judges of the RCPS with the first premium being awarded to Mr. Michael Loam:

for a machine which consisted of balanced rods working with a reciprocating motion in a shaft with platforms affixed to them at regular intervals . . .

By 1837 various scientific reports were being received in England concerning new technology that was being introduced in mines in Germany. In particular, *The Mining Journal* and *Commercial Gazette* of 1837 published a condensed version of

an earlier German paper that had originally appeared in the 1835 *Archiv für Mineralogie Geognosie, Bergbau und Huttenkunde*, edited by Karsten³. Of particular interest in this paper is a report from a Wilhelm Albert, an official in a mine in Clausthal in the Harz mountains, who describes a 'machine' for raising the lowering miners and also gives a detailed account of the manufacture of whim ropes made from iron wire.

With the possibility that answers to some their problems might already have been solved in Germany, and no doubt of the opinion that any plans which they were already considering would only benefit by observing machines that were already working elsewhere, on the 20th August, 1838 the RCPS:

resolved that Alfred Fox be requested to communicate with the Secretary of State of Hannover, soliciting the kindness of his assistance in procuring a sectional plan of the machinery used in the Harz for raising and lowering miners.

In the RCPS minutes of the 20th October, 1838 it is recorded that Alfred Fox had received a letter from the Minister of Hannover (dated 22nd Sept. 1838) who, it seems, more or less by return sent him the German publication of Karsten's 1835 work *Treatise on the machinery for raising miners*. In his letter, however, the Minister also promised to draw up and send on new plans of improved systems 'presently being used in the Harz mines'. It appears that these updated plans were sent and received by the RCPS in time to be read and recorded in their 12th November, 1838 meeting. In this same meeting it was also resolved that:

Mr. Alfred Fox be requested to communicate with the Minister of Science at Hannover requesting that he kindly send to the Society a specimen of the wire rope used in the mines of the Harz.

What exactly initiated this request for a piece of wire rope by the RCPS is not specified. The timing suggests that it came about as a result of reading the latest technical information received from Hannover; on the other hand it might have just been a timely response to Albert's article on wire ropes published in the 1837 Mining Journal.

Whether a sample of rope was ever received from Hannover is not reported. However, quite soon afterwards a John Basset⁴, a leading member of the RCPS, visited the mines in the Harz mountains, one assumes, to see for himself exactly how the man-engines installed there were working. The RCPS report of 1840 states that:

John Basset Esq. has favoured the Society with specimens of a miner's lamp and apron, and some iron-wire rope, used in the mines of the Harz, together with a communication on the machinery erected in these mines for raising the men, which appears to have been for some time in effective operation.

In Basset's communication he describes what he has seen at the mines around Clausthal, and is clearly very impressed with the wire rope that has been invented by the inspector of the Clausthal mine (Wilhelm Albert). Basset's communication reads:

The rope made for lowering and raising the bucket which

has twelve wires, and of which I send a sample, is a very great saving. The miners spoke of it as having every advantage over the old plan, particularly as to the duration and expense. As the inspector informed me, there was to the latter no less a saving than £2000 per annum.

His report continues:

No-one can form an idea of the pliability of the wire from the short piece of the specimen sent. It requires to have seen the rope coil round as the wheel revolved, with the regularity and ease of twine. I sincerely hope that it will attract attention in Cornwall. . . I have been in correspondence with some of the authorities in the Harz, for the purpose of obtaining a larger quantity of the wire so as to ascertain the comparative merits of the article manufactured there.

Lewis Gordon's interest in wire rope and his visit to the Harz mountains has already been mentioned. His communication to the RCPS, 'Abstract from notes on the power ladders used in the Harz mines' was published in the 1841 RCPS Annual Report. Again, Gordon's report principally concerns the use of power ladders for raising miners in the mines. However, in his communication he describes in detail the wire ropes used by Albert in the mines of Clausthal. Specifically he identifies that the wire ropes used are substantially thicker at the top than at the bottom. He says:

The ropes at the top consist of 36 wires, viz. three ropes of twelve wires The rope diminishes gradually, viz. four wires less for each 50 fathoms' descent

The reason for this graduation in rope thickness described by Gordon is simply to provide a rope of sufficient thickness at its top so that it will support the total load hung on it without breaking, while at the same time not being ridiculously oversized further down, since with increasing distance from the top of the shaft the rope supports a steadily reducing load. Although a number of shafts would have been used to descend to the lowest levels in a mine, the wire rope reinforced power ladder designed by Albert and used in the St. Andreasberg mine was continuous to a depth of 345 fathoms (2000 ft). Thus at the top of the mine the rope used would be 36 strands thick, 50 fathoms down it would reduce to 32 strands, 100 fathoms down it would reduce to 28 strands, and so on until from 300 to 345 fathoms it would be only 12 strands thick.

Typically in 1840, the maximum strength of wrought iron bar purchased from a foundry would have been about 300 N/mm² (20 tons/sq inch). In his published abstract in the 1837 *Mining Journal*, Albert identifies that each strand of wire making up his rope was 0.144 inches (3.7 mm) in diameter, would bear a tension of 10 cwt, and that 10 feet of this wire weighed 7¹/₅ ounces avoirdupois. From this information we can calculate that the maximum strength of Albert's wire was about 470 N/mm² (30 tons/sq inch). At first sight this figure appears to be rather high; on the other hand, if the original wire had been made from 'treble best' iron (i.e. the very best quality, highest strength iron, containing finely divided slag), and had in addition been cold drawn through successive dies down to its final diameter without subsequent annealing, then some increase in strength would be expected as a result of work hardening. In this state, however, that is after a number of

drawing reductions and in a fully work hardened state, the wire might well be expected to be difficult to handle during rope manufacture. In Albert's description of his rope making, he identifies that only one drawing reduction was made after annealing, following which the wire was immediately coiled on to a 12 ft diameter drum ready for use in the rope walkway. Recent experiments carried out by the author have shown that a 19th century, fully annealed wrought iron, 4 mm diameter rod, when drawn down from 4.0 mm to 3.7 mm will typically work harden by about 60% (Vickers hardness increasing from 125 N/mm² to 196 N/mm²). Such an increase in work hardening would, theoretically, increase the tensile strength of the iron from 300 N/mm² to about 480 N/mm² almost exactly the value of strength Albert reported for his wire.

Ten feet of a single strand of Albert's wire weighed 7¹/₅ ounces. Assuming a diameter of 0.144 inches, then one can calculate the density of Albert's wire to be 6.4 gm/cm³. The density of pure iron is 7.9 gm/cm³. The difference between these two values is indicative of the large amount of light-weight slag that would have been incorporated within the structure of 19th century wrought iron used in wire manufacture.

The internal structure of wrought iron manufactured in the 19th century can in some respects, be likened to a modern fibre composite material in which one might imagine a strong iron matrix containing directionally oriented weak slag fibres. An

illustration of the structure typical of early 19th century wrought iron is shown in Fig. 1. This figure shows clearly the iron (light coloured) and slag (dark) two-phase structure where the slag has been elongated in the direction of final working.

The manufacture of iron wire involves pulling a rolled iron rod through the hole in a steel die, where the diameter of the hole is slightly smaller than the diameter of the rod. This process of drawing is repeated using successively smaller dies until a wire of the required smallness in diameter is finally obtained. Not surprisingly, large slag inclusions in an iron rod could make continuous wire drawing extremely difficult, if not impossible, and for this reason, in the early 19th century, only the highest quality bar or rod ('treble best') was supplied for wire production. Figure 2 (a,b,c and d) shows various micrographs from an ~ 3.25 mm diameter wire made in approximately 1848. Figure 2a shows the wire with an uneven thickness where it has corroded along the whole of its length. However, at the end of the wire where it has been freshly cut and polished, it can be seen that the surface corrosion of the wire is literally only skin deep. Figure 2b shows the inherent soundness of the wire where the cut and polished end of the wire has been used as a mirror to reflect incident light. Figure 2c shows a polished cross-section through the middle of the wire while Fig. 2d shows a polished cross-section across the diameter of the wire. As well as illustrating a typical iron-

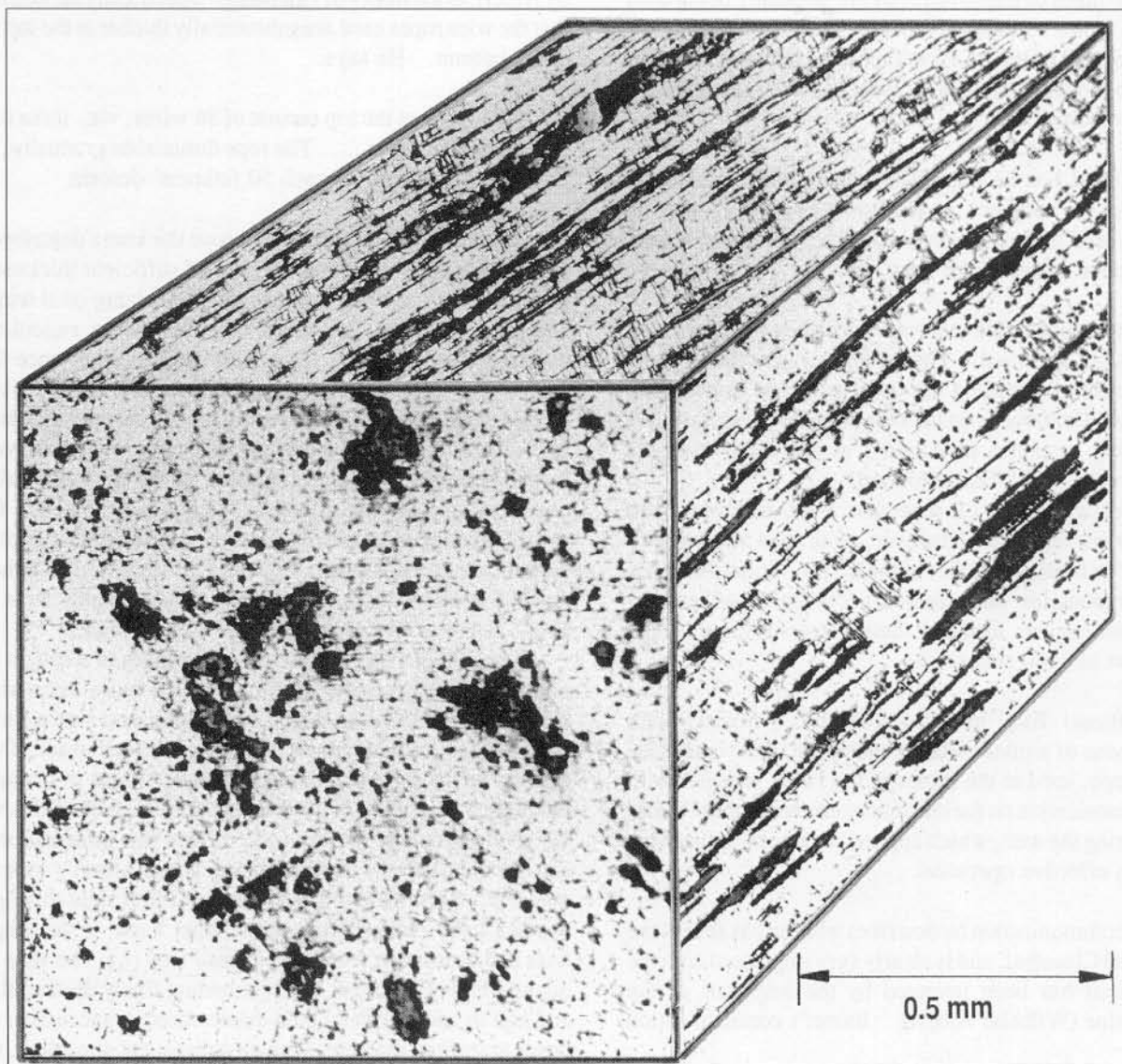


Fig. 1. Typical structure of early 19th century wrought iron.

slag structure within the wire, the cross-sections also give a good indication of how small the depth of surface corrosion is c. 150 years after manufacture.

In Gordon's 1841 RCPS report he calculates that the maximum total weight supported by Albert's ropes in the St. Andreasberg's 'man-engine' would have been 22 095 lb.

The stress produced in a 36 strand rope when supporting this load (with strands of 0.144 inches diameter) would have been 60 N/mm² - well below the maximum strength of Albert's rope of 470 N/mm² (nowadays described as a factor of static safety of ~8). If, however, Albert's design had used a constant cross-section rope of twelve strands for the whole of its 345 fathoms, then the stress at the top of the rope would have been ~1200 N/mm², i.e. representing a loading of approximately 2+ times more weight than the rope could have supported without breaking.

Following Gordon's 1841 report, the RCPS published another communication by a John Taylor in 1842⁵ titled 'On the machines for raising and lowering miners and on the use of the iron wire rope in the mining district of the Harz'. By this time, however, the first man-machine had been constructed in the Trevesean Mine in Cornwall (The RCPS 1843 report states that '....On the 5th January, 1842, the machine fixed to the depth of 27 fathoms was publicly tried.....'). Not surprisingly, therefore, Taylor makes a number of comparisons between the man-engines of Clausthal and Trevesean. However, from Taylor's communication it is clear that the concept and use of iron ropes was in the main still the preserve of the mines in Clausthal and the immediate area. Taylor reports that:

In the mines of the Harz nothing engaged my attention more than the universal employment of wire ropes for

drawing the ores and waste from underground. This appears to be to be one of the most important improvements in the economy of mines that has for some time been made, and as it is but now beginning to make progress in this country. I am induced to notice it in the hope that what experience may have been gained in Cornwall may be gathered at the next meeting of the Society, that the matter may be discussed, and the results made more generally known.

Taylor continues:

The first information respecting the use of wire ropes afforded to the English miner was by a paper which was communicated to the British Association in Newcastle, in the year 1838. It was not until the return of Professor Gordon from that country (Germany) that any attempt was made to avail ourselves of the improvement. Of late several persons have engaged in the manufacture, and great rivalry seems to exist as to claims to patents, and to superiority of quality.....

The rivalry that Taylor refers to is a reference to the bitter legal battles that took place over patent rights for the manufacture of wire rope between R.S. Newall & Co. (the wire rope company founded by Gordon after his visit to the Harz), and the partnership of Andrew Smith and George Binks, (and later Websters & Co.) who independently had been starting to manufacture and sell rope, not made of hemp, but of iron wire. Despite Taylor's request that information concerning the use and advancement of wire ropes in Cornish mines be gathered for discussion by the RCPS, their records make no mention of such a discussion ever having taken place. Certainly, however,

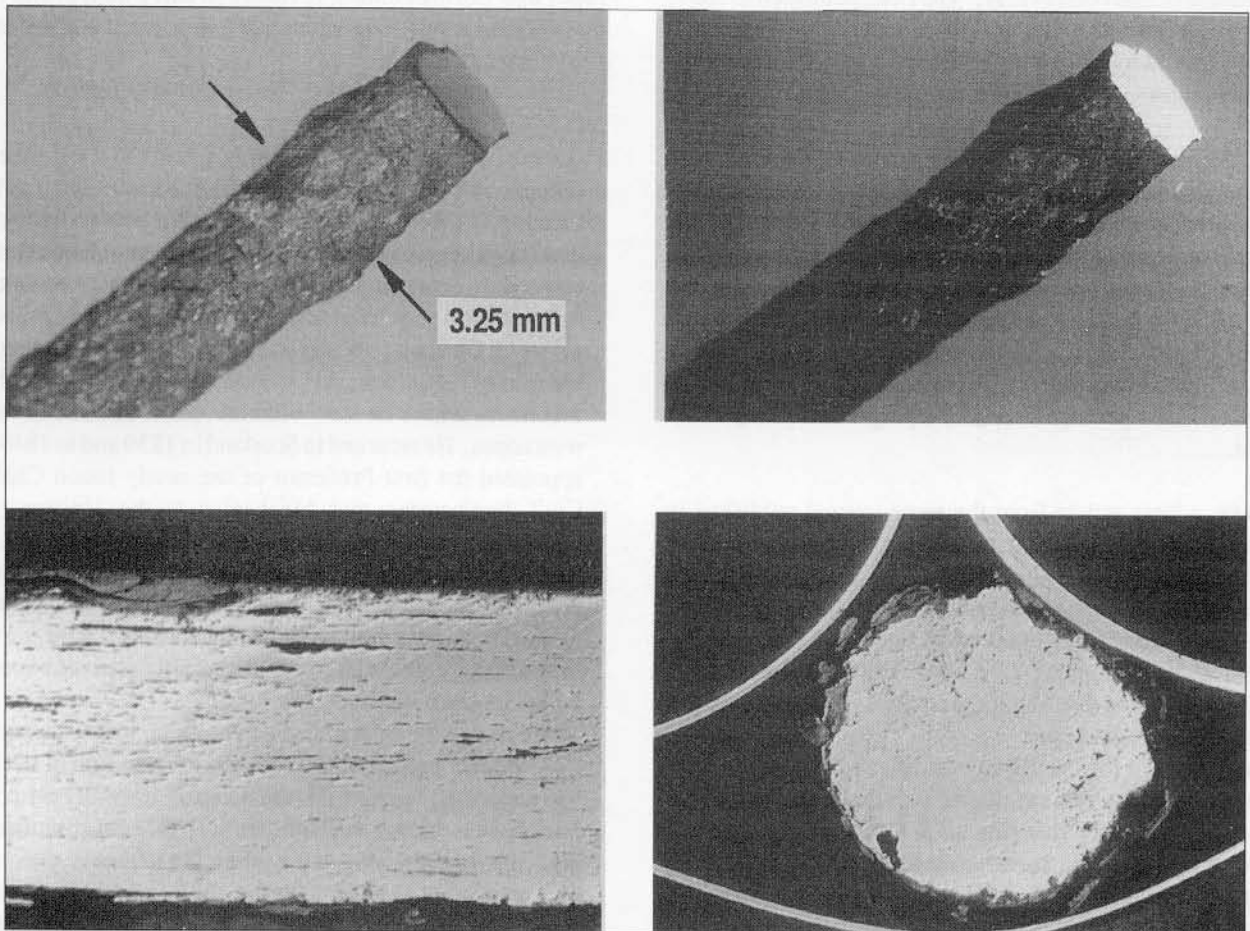


Fig. 2. Various micrographs from an ~ 3.25 mm diameter wire made in approximately 1848.

the growing use of wire rope in Germany was reported back to Cornwall. For example, in the 1845 RCPS report Charles Fox, writing about the mining industry in Saxony, identifies that the principal materials consumed included '4400 fathoms of wire rope'.

It can only be assumed that the introduction of wire ropes into the mining industry of Cornwall, and the U.K. in general, occurred slowly, and possibly with a certain amount of healthy suspicion, as the technology and manufacturing capability became established in the United Kingdom. It is recorded that in 1857 the South Wheal Frances mine was the first mine in Cornwall to use wire rope successfully. Records also show that wire rope was being used to a limited extent in mines in the Camborne area by 1866. However, the introduction and use of wire ropes was not without its dangers, as evidenced by the occurrence of one of the most serious mining accidents ever to occur in Cornwall. In August 1883, at the Wheal Agar mine, the wire rope hoisting a cage and thirteen men broke just as the cage reached the surface. One man, who had been illicitly riding on the roof of the cage, jumped clear, the rest were killed. It is not unreasonable to suppose that miners generally were rightly suspicious of new, untried practices which they might consider added extra danger to their already hazardous existence. There was certainly concern that wire ropes would soon oxidise when damp and would become 'considerably weakened' (Taylor's report of 1842), and that such a weakening, if it occurred within the strands of the rope, would easily escape observation.

Even nearly twenty years after John Taylor had urged the members of the RCPS to gather information concerning the use of wire ropes and to 'make results more generally known', controversy still seems to have surrounded the replacement of hemp ropes by wire. Two articles from *The Engineer* illustrate clearly some of that controversy. The first, published in 1857, seems to indicate that the future of wire ropes was well secured. Following comparative tests of wire vs. hemp ropes, the article states:

...the straining tests show the immense superiority of wire ropes over that made even from the best fibrous material, . . . we observe that wire rope is a fourth less in weight, and not one half the bulk of that made of hemp of the relative strength and enduring capacity. . . . we cannot but come to the conclusion that wire rope seems destined, ere many years, greatly to surpass, if it shall not entirely supersede, hemp rope. . . . Already, indeed, we see that for years it has been gradually creeping into more general use. . . .

However, a later article from the same journal published in 1860 which describes the public tests of wire ropes reports that a piece of wire rope made by Newall & Co. 1⁷/₈ in, weighing 3 lb per fathom, was then tested and broke at 5 tons. A piece of 4¹/₂ in Manila rope manufactured by Garnock, Bibby & Co. was next tested, weighing 2³/₄ lb per fathom, and broke at 8 tons 5 cwt., showing that Manila hemp rope is stronger, weight per fathom than wire rope.

The argument for identifying the inferior performance of wire rope over hemp is to say the least a tortuous piece of logic, and it should be added that Newall & Co. strongly protested as to how the tests had been carried out, to the extent that further tests were later arranged. However, the printing of such an article at all in *The Engineer* must, to some extent, indicate that a certain feeling of distrust against iron ropes

existed in England 25 years after they had been successfully used and promoted in the mines around Clausthal and Zellerfeld in the Harz mountains.

Certainly there is evidence to support the suggestion that the miners of Cornwall remained suspicious of wire ropes for a substantial period of time. For example, The 1887 *Transactions of The Mining Association and Institute of Cornwall* published an article by R.J. Frencheville, an inspector of mines for Cornwall & Devon, titled 'Some remarks on winding appliances and round wire ropes'. This paper chiefly concerned the use and misuse of steel ropes, rather than iron ropes, the former by this time becoming more readily available and exhibiting advantageous breaking strengths typically of between 40 tons/sq inch and 120 tons/sq inch, depending on steel type and quality of manufacture. Frencheville draws the reader's attention to recent mining catastrophes which occurred as a result of wire ropes (one assumes made of both steel and iron) breaking during use. Of greater interest, however, is the comment made in the written discussion of Frencheville's paper by a Mr. Stephens, from Falmouth, who was a wire rope manufacturer in that district. Mr. Stephens points out that:

a rule still exists in most of the mines of the district (a regulation made not by the Government but by the mine authorities) that miners should not ascend or descend by a wire rope.

One assumes that this rule was not enforceable and that some mines, such as Wheal Agar where failure of wire rope led to loss of life, were using wire rope to lift men well before this date. From Mr. Stephen's statement, however, it can only be concluded that even as late as 1887, the introduction of wire ropes into Cornish mines, certainly to carry men to and from the working levels, was a practice that was not considered as either proven or safe.

NOTES

1. Lewis Gordon was born in Edinburgh in 1815 and educated himself to pursue a career in engineering. At the 1834 meeting of the British Association in Edinburgh he met the great engineer Brunel and following this meeting subsequently worked as Brunel's assistant. At the age of 23 he decided to complete a short course of study at the Freiburg school of mines in Germany. While at Freiburg in 1838, during the university vacation, he visited the mines in the Harz mountains where he met Wilhelm Albert and saw Albert's wire ropes. He returned to Scotland in 1839 and in 1840 was appointed the first Professor of the newly found Chair of Civil Engineering and Mechanics at the University of Glasgow. It is interesting to note that at this time, his appointment was regarded with jealousy and irritation by the university establishment, attitudes typified, for example, by the fact that in the following years he was left to argue with the university authorities even for an allocation of a room in which to teach his students.
2. The Fox family represented a dynasty of highly respected, rich, Quaker merchants established in Falmouth in 1759. It was under their auspices that the (Royal) Cornwall Polytechnic Society was started in Falmouth in 1833. 'to stimulate the ingenuity of the young and to elicit the inventive powers of the community at large'. In the 1833 and 1834 records of the RCPS a number of Fox's are mentioned as acting as beneficiaries to the society. C. (the seventh son) and R.W.

Fox for each offering 'premiums' to be awarded at the next RCPS exhibition, and G.C. and J.F. Fox for each loaning to the exhibition paintings from their private collections including works by no lesser artists than Moreland, Vandyck, and Titian. One assumes that all the Fox's identified in the early RCPS reports shared the same family roots.

- 3 Dr C.J.B. Karsten was an eminent scientist interested especially in iron manufacture. He was editor of the four-volume *Handbuch der Eisenhüttenkunde* first published in 1816. It is interesting to note that in the fourth volume of this work are specific details referring to wire production and manufacture.
- 4 John Basset (1791-1843) was a leading member of the RCPS, and by 1840, a vice president. He was sheriff of Cornwall in 1837 and was also elected as member of parliament for Helston in 1840.
- 5 John Taylor FRS (1779-1863) travelled at the age of 19 from his native Norwich to take up the post of manager of the Wheal Friendship Mine in Cornwall. He was elected a Fellow of the Royal Society in 1825. Clearly throughout his life he maintained an active involvement with the RCPS, in whose records it is reported that he offered various premiums etc. e.g. the RCPS report for 1840 states.. "A premium of five guineas, by John Taylor FRS for the most complete and accurate accounts of . . .

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